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REVIEWS OF BOOKS.

An Enquiry concerning the Principles of Natural Knowledge. By A. N. WHITEHEAD. Cambridge University Press, 1919.—pp. xii, 200.

It is very much to be feared that this work, like the classic and unobtainable treatises of Cournot, may fail to obtain the immediate recognition which it deserves. It contains too much mathematics to appeal to the greater number of philosophical thinkers, and too much epistemology to appeal to the greater number of mathematicians or physicists. And even those who might otherwise be attracted will in many cases be repelled by the extraordinary condensation of the material. What is crammed into these few pages might with profit have been expanded to fill at least three large volumes. It is very difficult reading throughout. It must be studied line by line and word by word, and, at the same time, with a constant view to the interconnections between the different parts of the work. But it will well repay the pains that are expended upon it. And with regard to the mathematics it may be said that there is little that should fatally embarrass anyone who has had the ordinary undergraduate training in the subject. Not that the present reviewer can claim to understand every point clearly. Three readings of the book are really necessary, and he has had time for only two.

Mr. Whitehead appears to have felt very keenly the force of Bergson's criticism of natural science as incapable of expressing the continuity of things. But he finds the criticism to apply, not to science as it may be, but to science as it has been; and the ulterior aim of his whole work is to reform science so that it shall no longer be open to any such criticism. He writes (p. 4): "The ultimate fact embracing all nature is (in this traditional point of view) a distribution of material throughout all space at a durationless instant of time, and another such ultimate fact will be another distribution of the same material throughout the same space at another durationless instant of time. . . . Some modification is evidently necessary. No room has been left for velocity, acceleration, momentum, and kinetic energy, which certainly are essential physical quantities." And he adds (p. 6): "The fundamental assumption to be elaborated in the course of this inquiry is that the ultimate facts of nature, in terms of which all physical and biological explanation must be expressed, are events connected by their spatio-temporal relations, and that these relations are in the main reducible to the property of events that they can contain (or extend over) other events which are parts of them. In other words, in the place of emphasising space and time in their capacity of disconnecting, we shall build up an account of their complex essences as derivative from the ultimate ways in which those things, ultimate in science, are connected."

I do not think that it derogates greatly from the value of Mr. Whitehead's contribution to hold that it does not have the significance which he here ascribes to it. Whether or not the Bergsonian criticism of science is sound, the new primacy of the relation of extending-over does not, I feel sure, add anything in the way of continuity to the scientific view of nature. Wholes and parts, as we shall see, are arranged in series and rearranged in other classes in the most external fashion in the world. And as to the connection between the space of one instant and the space of another—the identity of the same place at different times—that does not arise from the relation of extending-over, but is imported into the system as a second indefinable relation, that of 'cogredience.'

The central feature of the work is the author's method of arriving at definitions of such concepts as the mathematical point,—the "method of extensive abstraction," as he calls it. For the most part, in studies in the foundations of geometry, the point has been accepted as an indefinable, and solids have been regarded as 'sets' of points. It occurred to Mr. Whitehead, that, however justifiable such procedure might be from the mathematician's standpoint, it was far from representing the order of experience; for in experience points are certainly not data but constructs.

Mr. Whitehead's definitions are given in terms of the events occurring in space and time; but in order to get before us an easy illustration of the method, let us assume as indefinable the solids of ordinary geometry. Our object, then, will be to reverse the ordinary procedure and define the point as a set of solids, *i.e.*. the set of those solids which would ordinarily be said to contain the point. As an indefinable relation we assume that of whole and part, which we call "extending over." Conceive now a series of solids—such as concentric spheres, for example—each of which extends over all that follow it in the series. Let the series be unending in one direction; that is to say, let there be no member of the series which does not extend over other members. As so far defined, the members of the series might all extend over some one solid; for example, in the case of the concentric spheres, they might diminish in such a way as to converge upon a certain sphere as their limit. Let us remove this possibility by specifying that the series of solids which we are considering must be such that there is no solid that is extended over by every member of the series. Such a series we shall call an 'approximation-route.' In ordinary terms, we should say that since it does not converge upon a solid, it must converge upon a surface, a line or curve, or a point.

Our next step must be to distinguish those approximation-routes that converge upon points. To do this, let us imagine a series of cylinders having a common axis, upon which they converge: also a series of concentric spheres converging upon their center, which shall be the middle point of the cylinder-axis. We perceive at once that there is no cylinder so small but that there is some sphere that it extends over; but the diameter of a sphere may easily be too small for it to extend over any of the cylinders. We say then, that the series of cylinders covers the series of spheres, but that the series of spheres does not 'cover' the series of cylinders. In general terms, if for every member of an approximation-route A there is a member of an approximation-route B which it extends over, then A is said to 'cover' B. If, instead of cylinders, we had had concentric cubes, having the same center as the spheres, every sphere would extend over some cube and every cube would extend over some sphere; thus the two approximation-routes would *cover each other.* We now perceive that those approximation-routes which converge upon points are distinguished by this property: that *such an approximation-route cannot cover any other that does not cover it.*

Let us now consider one approximation-route having this last-mentioned property; and let us further consider the class of solids which are *members of any of the approximation-routes which this approximation-route covers.* This class of solids is a point.

What, then becomes of the point in the old sense of an infinitesimally long solid? It is dropped out of science as a superfluous assumption. The geometrical properties of the new points are precisely the same as those of the old ones. And although the infinite series of solids that make up the approximation-routes are a good deal to assume, still there is this to be borne in mind (as Mr. Bertrand Russell notes): that the old-fashioned assumption of infinitesimal solids logically involved the assumption of approximation-routes converging upon them; while the assumption of the approximation-routes does not involve that of the infinitesimal solids.

To my mind, the method which has just been illustrated is not only an important addition to science, but an even more important contribution to philosophy. But in evaluating it there is one further consideration that I would suggest. The point, as an infinitesimal solid, lay beyond the limits of any possible experience. Its existence or non-existence was beyond any empirical test, direct or indirect. In the case of such objects, existence means no more than logical possibility. There never has in fact been recognized any difference between a possible point and an actual one. Accordingly, the traditional assumption did not really go beyond the new one. And hence Mr. Whitehead has done something better than merely giving us new points for old. He has given us an extraordinarily clear analysis of what was involved in the assumption of points.

It has been remarked that Mr. Whitehead's own point of departure is not the conception of solids but the conception of events—that which occurs during a certain lapse of time at a constant or continuously variable place. An event is thus a four-dimensional entity: in addition to time, it has the three dimensions of space. An event never occurs but once. Other events, resembling it as precisely as you please, may occur; but they are not it. It is *objects* that recur; and it is the recognition of objects that is the beginning of organized knowledge.

According to Mr. Whitehead, the relation of whole to part obtains primarily only of events, while objects as such are atomic. The same object, as he points out, occurs at different times and different places, as it is situated in different events. But each such time or place is only contingently that of the object, while it is essentially that of the event. Hence it is only as situated in an event that an object is in time or space; and Mr. Whitehead infers that therefore it is only as situated in an event that an object can have either temporal or spatial parts. Mr. Whitehead lays a great deal of emphasis upon this doctrine, which he regards as of essential importance for the philosophy of nature. It appears to me that the doctrine is clearly unsound, and, moreover, that it does not affect Mr. Whitehead's further theories in the least. We recognize the same object as having the same parts at different times and places, that is to say, in every one of a certain class of situations. Accordingly, it is not as actually in a situation, but as *possibly* in a situation that the object has spatial parts. So far as the object possessing its parts is concerned, the situation is only (as the mathematical logicians say) an 'apparent' variable. When, therefore, Mr. Whitehead writes (p. 66): "The continuity of nature is to be found in events, the atomic properties of nature reside in objects," he appears to be in error.

There is a very interesting discussion (in Chapter VI) of the various classes of objects that the author conceives to be essential to scientific thought. These are sense-objects (*i.e.*, sensations, whether internally or externally excited); perceptual objects, which are regarded as associations of sense-objects which are more or less persistent and are subject to more or less modification without the loss of their individuality; physical objects, which are merely 'non-delusive' perceptual objects; and, finally, scientific objects, such as the molecule and the electron, which are not directly perceived, but are inferred by reason of their capacity to express the causal characters of events (p. 95). This last part of the discussion is in fundamental agreement with the famous principle of the ancient atomists: that science must start from phenomena, and must so conceive the reality behind the phenomena as thereby to explain the phenomena.

There is at least one serious blemish in this part of the work; namely, the confusion, so long traditional in English philosophy, between the sensation-quality on the one hand and the secondary quality of a perceived object on the other hand. The distinction is important because a change in a sensation-quality may be interpreted by us as due, or as not due, to a change in the secondary quality of the object, and the distinction is *not* based on the magnitude of the change. Thus a difference in sensation-qualities of vision may be attributed to the state of the percipient organism (as in the case of adaptation), to the illumination, or to the fading of the color; and the fading of colors, let us note, was observed long before molecules or electrons were dreamed of. What the color (in the sense in which it is subject to fading) is, can be determined by a method with which Mr. Whitehead is very familiar; namely, by considering the condition under which two objects are said to have the same color. The condition is that, under like physical and physiological conditions, the visual sensation-qualities shall *vary together*. A moment's consideration of this fact should convince Mr. Whitehead that he has confused two radically different things; and further reflection will then, I am sure, lead him to the conclusion that perceptual objects and scientific objects are not so disparate as he has supposed.

Part III contains an outline of a four-dimensional geometry of events in space and time, which is intended to take the place of Einstein's 'signal-theory' as a basis for the interpretation of electromagnetic phenomena. It is professedly a work of simplification. As the author remarks (p. vi): "The whole investigation is based on the principle that the scientific concepts of space and time are the first outcome of the simplest generalizations from experience, and that they are not to be looked for at the tail end of a welter of differential equations." It appears to me to be a very remarkable piece of mathematical construction. The author, however, claims more for it. Whereas other investigations have been concerned with geometry as an abstract science deduced from hypothetical premises,—"In this enquiry we are concerned with geometry as a physical science. How is space rooted in experience?" (p. v). Any very elaborate notice of this part of the work would be in place only in a mathematical journal. But there are certain features that may properly call for comment, or at least mention, here.

The events that are assumed are all finite in their temporal dimension; but some are infinite in all their spatial dimensions. These are called 'durations.' A duration, as thus defined, is a "temporal slab of nature," not an abstract lapse of time. Durations, I repeat, are assumed as given in experience. The author holds, in fact, that every spatially finite event "is apprehended as related to a complete whole of nature which extends over it" (p. 77).

One duration may extend over another (briefer) duration; but it is assumed that no event except a duration can extend over a duration.[1] These facts enable the author to give a definition of a *moment, i.e.*, a whole of nature at a given instant of time. Consider an approximation-route of events (an 'abstractive-class,' as he calls it) with the property that it covers every abstractive class that covers it. Since the only unbounded events are assumed to be durations, the members of this class must all be durations. Then consider the whole class of abstractive classes that cover this abstractive class. All will be routes of approximation to the same ideal limit. Now, finally, consider the class of all the members of these abstractive classes; and that is a moment.

As is now common in electro-magnetic theory, a plurality of time-systems is assumed. If two durations are such that there is a duration that extends over them both, they belong to the same time-system; otherwise not. The moments that are determined by durations belonging to different time-systems, themselves belong to different time-systems. Durations and moments belonging to different time-systems intersect, so to speak, *obliquely*. This circumstance enables the author to define the planes, straight lines, and points of the instantaneous space of a moment. An instantaneous plane (or 'level') is the intersection of two non-parallel moments. Three moments, under certain conditions, suffice to determine a 'rect,' and four a 'punct,' as the instantaneous straight line and point in the space of a moment are called. Parallelism of levels and rects is derived from the relation between moments of the same time-system, as they are intersected by a moment of another time-system.

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[1] This would seem to imply that an event must, so to speak, begin all over at once. Otherwise one might say, for example, that the duration consisting of the history of the universe on February 29, 1920, Greenwich time, was extended over by the event consisting of that history together with all that happened in the previous twenty-four hours within five thousand miles of the center of the earth. However, this limitation is nowhere explicitly laid down. Students of Mr. Whitehead's book will also observe that if events are limited in this way, then every event, and not merely a duration, is relative to a particular time-system.

The indefinable relation of 'cogrediance,' or rest within a duration, is now introduced, and at once makes possible the definition of the 'point-track,' or point considered as existing at all the moments of a time-system. The point-track is then said to be 'normal' to the moments of its time-system; and from this relation of normality, the relation of perpendicularity is derived. Finally, the theory of linear measurement is based, first, upon the equality of the opposite sides of a parallelogram, and, secondly, upon the principle, that if the perpendicular bisector of one side of a triangle passes through the opposite vertex, the triangle is isosceles. (The measurement of time is based upon the study of velocities; and the theory is too complicated to be indicated here.)

Mr. Whitehead says in comment upon all this (p. 115): "The electromagnetic theory of relativity [involving a plurality of time-systems] . . . has also the merit of providing definitions of flatness, of straightness, of punctual position, of parallelism, of time-order and spatial order as interconnected phenomena, and (with the help of cogredience) of perpendicularity and congruence. The theory of extension has also provided the definition of a duration." It is, indeed, a remarkable example of mathematical elegance that we have set before us. But when we are asked to consider it as an answer to the question, "How is space rooted in experience?" we must be pardoned if we dissent. For in this regard no refutation of the theory could be more fatal than Mr. Whitehead's summary of its merits. Could any fiction be less plausible than this: that it is from the observation of different time-systems that we derive the notions of flatness, straightness, parallelism, and perpendicularity, to say nothing of spatial measurement? If it be sound doctrine, "that the scientific concepts of space and time are the first outcome of the simplest generalizations from experience," this is certainly not a satisfactory account of their genesis.

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